

The use of a 3-dimensional computed tomography bone database to evaluate the risk of distal contact between the rasp tip and the endosteal cortical bone

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ABSTRACT

Purpose. To use a 3-dimensional computed tomography (CT) bone database to evaluate the risk of distal contact between the rasp tip and the endosteal cortical bone.

Methods. Using a 3-dimensional CT bone database, the rasps for Exeter stems of 125 mm in length and body size 1, with a femoral offset of 37.5, 44, or 50 mm were compared with those for Exeter stems of 150 mm in length and same body size with the corresponding femoral offset. Rasp geometry was determined using an engineering drawing software.

Results. Of the 631 femurs in the database, 238 (187 Caucasian and 51 Asian) were of appropriate femoral offset and proximal body size to receive a stem with an offset of 37.5, 44, or 50 mm. Of these, 145 (115 Caucasian and 30 Asian) femurs were of champagne-flute type; the prevalence was comparable between the 2 populations (61% vs. 59%, $p=0.729$). When using the 150-mm rasp, 70 (55 Caucasian and 15

Asian) of the 238 femurs had distal contact between the rasp and femoral cortex; the prevalence was comparable between the 2 populations (29% vs. 29%, relative risk=1.0, $p=1.0$). Distal contact between the rasp and femoral cortex occurred more commonly in champagne-flute-type femurs than other femurs in the anteroposterior plane (28% [41/145] vs. 2% [2/93], relative risk=13.1, $p<0.001$) and in the mediolateral plane (27% [39/145] vs. 14% [13/93], relative risk=1.92, $p=0.019$). When using the 125-mm rasp, only one femur (with a canal flare index of 4.52) had distal contact in the mediolateral plane with an offset of 37.5 mm. Distal contact between the rasp and femoral cortex occurred more often with the 150-mm rasp than the 125-mm rasp in both planes ($p<0.001$).

Conclusion. The use of a shorter stem may enhance anatomic fit in patients with a narrow femoral canal and prevent distal contact between the rasp and femoral cortex.

Key words: arthroplasty, replacement, hip; femur

INTRODUCTION

The use of the Exeter cemented polished tapered stem (Stryker Orthopaedics, Mahwah [NJ], USA) in total hip replacement (THR) has resulted in excellent long-term outcome and survival.¹⁻³ It can be used for primary and revision THR and is available in a wide range of femoral offsets, body sizes, and lengths to achieve anatomic restoration. Most Exeter primary stems have a shoulder-to-tip length of 150 mm and a femoral offset of 37.5 to 56 mm.

To correct stem insertion and allow space for the cement mantle, a rasp slightly larger than the stem with similar geometry is used. In patients with a narrow femoral canal ('champagne flute' or Dorr A type), cortical contact may occur distally with the rasp and this may restrict re-creation of the correct femoral offset with a 150-mm length stem.⁴

Shorter Exeter stems (95 to 125 mm) are available with offsets of 30 to 35.5 mm. According to the Australian National Joint Replacement Registry, these shorter stems have achieved excellent survival at 7 years, comparable with 150-mm-length stems.⁵ Nonetheless, shorter stems are not available with offsets >35.5 mm or body size No. 1.

This morphometric study used a 3-dimensional computed tomography (CT) bone database to evaluate the risk of distal contact between the rasp tip and the endosteal cortical bone, and determine whether shorter stems can enhance anatomic restoration for champagne flute femurs.

MATERIALS AND METHODS

SOMA (Stryker Orthopaedics Modelling and Analytics technology, Mahwah [NJ], USA) is a 3-dimensional CT bone database that comprises CT scans and anatomic analysis and implant fitting tools of osseous structures from patients with non-orthopaedic maladies.⁶ It provides accurate outer and inner cortical geometry, with cortical bone defined as a Hounsfield value >500 HU.

Of 631 femurs in the SOMA database, 523 are from a Caucasian population and 108 from an Asian population aged 18 to 93 (mean, 62.4) years. The proximal femoral canal axis is defined by the 2 points of the inner cortical boundary at 2/10 and 3/10 the total length of the femur (Fig. 1). The broach and reamer are likely to centre around this axis. The anteroposterior (AP) and mediolateral (ML) planes are defined according to the centre of the femoral head (Fig. 1).

Using the SOMA database, rasps for Exeter stems

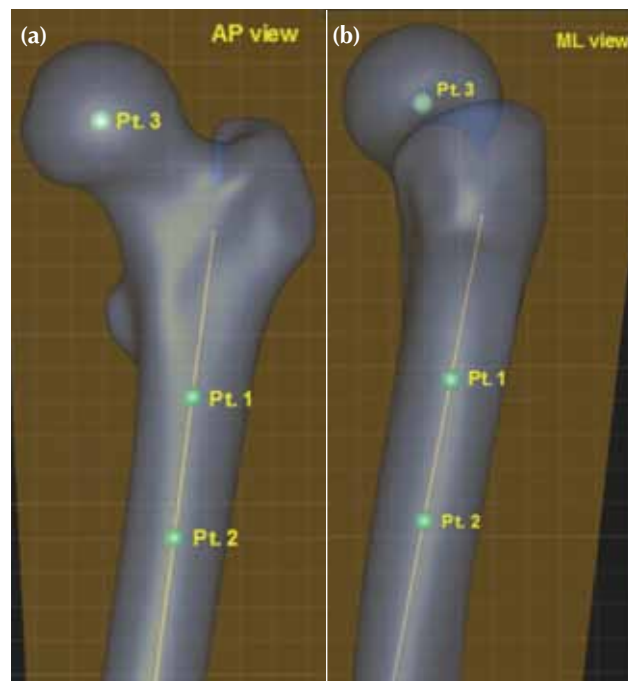


Figure 1 (a) Anteroposterior and (b) mediolateral views of the outer cortical bone boundary of a model bone.

of 125 mm in length, body size 1, with a femoral offset of 37.5, 44, or 50 mm were compared with those for Exeter stems of 150 mm in length and same body size with the corresponding femoral offset. Rasp geometry was determined using an engineering drawing software. On the AP plane, it comprised the femoral offset, rasp width 80 mm distal to head centre, and distal rasp width. On the ML plane, it comprised the proximal and distal rasp width.

Femurs of appropriate femoral offset and proximal body size (mid-prosthesis cancellous bone width, Fig. 2a) in the AP plane were selected from the SOMA database for the stems of interest. The femoral offset was compared with the stem offset; the lower/upper boundaries of acceptance for each stem offset were defined by comparing the stem offset (e.g. 44 mm) with the smaller/larger offset (e.g. 37.5/50 mm) and taking the mid-point between these stems' centreline offset (offset axis defined by the taper in the AP view). The measurement for mid-prosthesis inner cortical boundary width was compared with the mid-prosthesis width in order to establish appropriate metaphyseal implant/bone fit; the lower boundary for acceptance was the mid-prosthesis rasp width (rasp for stem fits within cortical boundary), and the upper boundary for acceptance was this width plus 2 mm medially or laterally (to impose a

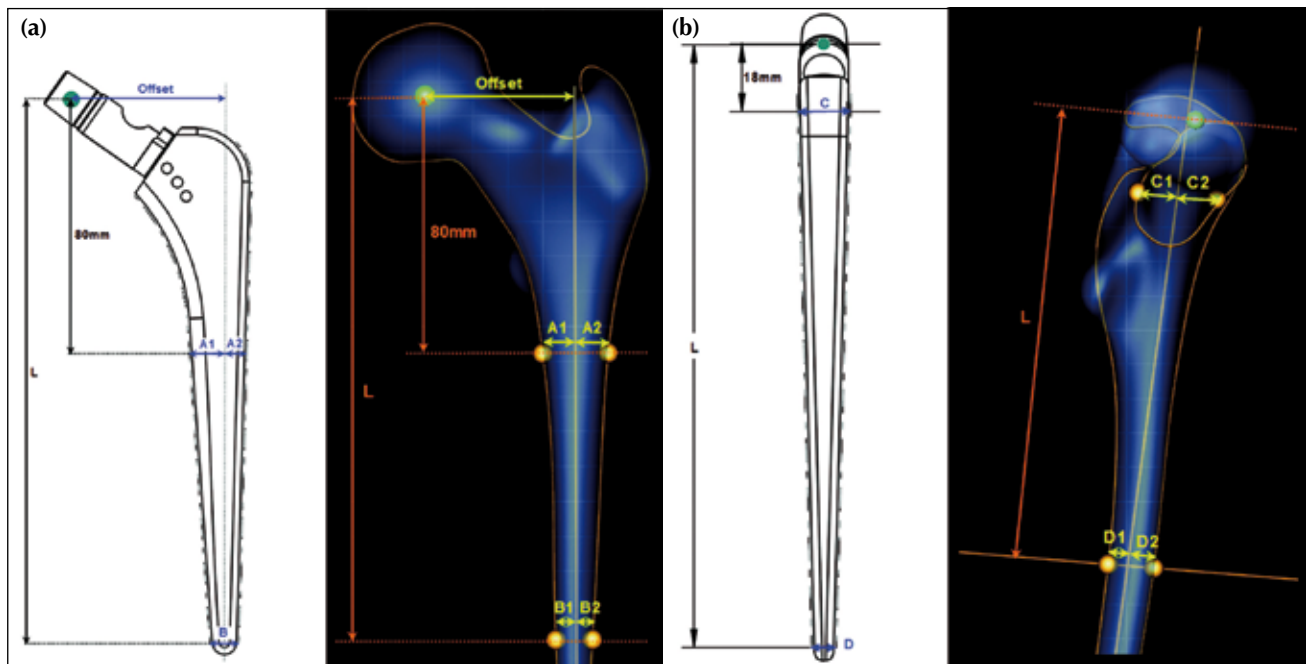


Figure 2 (a) Anteroposterior and (b) mediolateral views of a rasp and a model bone for determination of distal contact between the rasp and femoral cortex

limit for amount of cancellous bone bed remaining for implant to not be undersized). For additional analysis, measures of inner cortical boundary width in the AP plane were taken 20 mm below the lesser trochanter and at the isthmus, identified as the narrowest section of the medullary canal, in order to find the canal flare index. If the femur satisfied the Noble Index criteria of a canal flare index >4.7 , it was defined as the champagne-flute type.⁷

Once bones with the appropriate offset and canal fill ratio were identified, the risk of distal contact of the rasp was assessed by comparing the width of the rasp with the width of the inner cortical boundary at the distal tip of the rasp. In the AP view, the rasp was aligned with the femoral axis. To determine whether the rasp contacted distally, the half width of the rasp tip in the AP view was compared with the distance from the femoral axis to both the medial and the lateral inner cortical bone boundaries at the distal tip of the rasp (Fig. 2a). In the ML view, the rasp was initially assumed to align with the femoral axis, but could be flexed to ensure it passed through the femoral neck. The degree of flexion was determined by applying a reiterative process until the rasp passed through the femoral neck where the rasp body began (transition from broach post to body 18 mm distal to head centre) while staying as close as possible to the femoral axis

(Fig. 2b). When the rasp's new axis was found, the risk of distal contact was assessed by comparing the half width of the rasp distal tip in the ML view with the distance from the new axis to both the anterior and the posterior cancellous-cortical bone boundaries at the tip of the rasp (Fig. 2b).

The rates of distal contact between Caucasian and Asian populations and between champagne-flute-type femurs and other femurs for each rasp size were compared using Pearson's Chi-squared test. Relative risks with 95% confidence intervals (CI) were presented. The number of femurs with distal contact with the 125-mm rasp and the 150-mm rasp (with an offset of 37.5, 44, or 50 mm) were compared using McNemar's test for matched samples. A p value of <0.05 was considered statistically significant.

RESULTS

Of the 631 femurs, 238 (187 Caucasian and 51 Asian) were of appropriate femoral offset and proximal body size to receive a stem with an offset of 37.5, 44, or 50 mm. Of these, 145 (115 Caucasian and 30 Asian) femurs were of the champagne-flute type; the prevalence was comparable between the 2 populations (61% vs. 59%, $p=0.729$).

When using the 150-mm rasp, 70 (55 Caucasian and 15 Asian) of the 238 femurs had distal contact between the rasp and femoral cortex in the AP (n=18) or ML (n=27) plane or both (n=25); the prevalence was comparable between the Caucasian and Asian populations (29% vs. 29%, relative risk=1.0 [95% CI=0.62–1.62], $p=1.0$). Distal contact between the rasp and femoral cortex occurred more commonly in champagne-flute-type femurs than other femurs in the AP plane (28% [41/145] vs. 2% [2/93], relative risk=13.1 [95% CI=3.3–53.1], $p<0.001$) and in the ML plane (27% [39/145] vs. 14% [13/93], relative risk=1.92 [95% CI=1.1–3.4], $p=0.019$, Table 1).

When using the 125-mm rasp, only one femur (with a canal flare index of 4.52) had distal contact in the ML plane with an offset of 37.5 mm; distal contact between the rasp and femoral cortex occurred more often with the 150-mm rasp than the 125-mm rasp in both planes ($p<0.001$, McNemar test, Table 2).

DISCUSSION

The cemented Exeter hip stem has achieved up to 100% survival at 17 years (with aseptic loosening as the endpoint of revision).^{1,3,8–10} Nonetheless, it is important to match the prosthesis size to achieve

optimal outcome.¹¹ In patients with a narrow femoral canal, the 150-mm stem is too wide and necessitates additional reaming to remove the cancellous bone including the strongest trabecular bone near the corticocancellous bone junction (within 3 mm of the cortex), which is the ideal bed for cement fixation.¹² Many of the femoral components are too large for patients with a small femoral canal, resulting in cement mantle <2 mm thick.¹² Loosening of the femoral component usually occurs in femurs that have been reamed, or when the femoral component is over-sized.¹²

Shorter stems of 95, 105, and 115 mm in length with the respective offset of 30, 33, and 35.5 mm have been developed and have achieved excellent outcome in smaller patients.^{4,13} Nonetheless, in patients with a narrower medullary canal and offset of >35.5 mm, restoration of anatomy remains a challenge. The geometry of the proximal femur is determined by genetic and environmental factors that include age, race, sex, and lifestyle.¹⁴ The femoral offset is independent of the canal width such that some patients with a narrow distal femoral canal have a high femoral offset.⁷

In some patients with a canal flare index of 4.7, alternative sizes of the femoral component may be needed to reduce the risk of distal contact between

Table 1
Distal contact in champagne-fluted femurs with a 150-mm rasp in anteroposterior and mediolateral planes

Plane	Femur type	No. (%) of distal contacts		RR (95% CI)	p Value
		Contact	No contact		
Anteroposterior	Champagne flute	41 (28.3)	104 (71.7)	13.1 (3.3–53.1)	<0.001
	Non-champagne flute	2 (2.2)	91 (97.8)		
Mediolateral	Champagne flute	39 (26.9)	106 (73.1)	1.9 (1.1–3.4)	0.019
	Non-champagne flute	13 (14.0)	80 (86.0)		

Table 2
Distal contact in femurs with a 150-mm versus 125-mm rasp

Plane	No. of distal contacts								p Value
	150-mm rasp				125-mm rasp				
	Femoral offset			Total (n=238)	Femoral offset			Total (n=238)	
	37.5 (n=62)	44 (n=120)	50 (n=56)		37.5 (n=62)	44 (n=120)	50 (n=56)		
Anteroposterior	8	16	19	43 (18.1%)	0	0	0	0 (0.0%)	<0.001
Mediolateral	12	29	11	52 (21.8%)	1	0	0	1 (0.4%)	<0.001
Total	14	36	20	70 (29.4%)	1	0	0	1 (0.4%)	<0.001

the rasp and femoral cortex in the ML plane. The use of shorter stems may enhance anatomic fit in some patients and subsequent long-term fixation and implant survival.¹⁵

One limitation of this study was that it was a modelling study based on CT scans in a non-arthritic population. Nonetheless, it is an important step to assess the clinical need for shorter rasps to enhance anatomic fit in some patients.

CONCLUSION

The use of a shorter stem may enhance anatomic fit

in patients with a narrow femoral canal and prevent distal contact between the rasp and femoral cortex.

ACKNOWLEDGEMENT

Emmalynn Connor and Thies Wuestemann are paid employees of Stryker Corp. Jonathan R Howell and Ross W Crawford receive royalties and research support from Stryker Corp. Jonathan R Howell is a member of the British Hip Society Executive Committee. The position of Sarah L Whitehouse is partially funded by Stryker Corp via an external institution. No funding was received specifically for this project.

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